Application of a dislocation based model for Interstitial Free (IF) steels to Marciniak Stretch test simulations

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With a view to environmental, economic and safety concerns, car manufacturers need to design lighter and safer vehicles in ever-shorter development times. In recent years, High Strength Steels (HSS) like Interstitial Free (IF) steels, which have ratio of yield strength to elastic modulus, are increasingly used for sheet metal parts in automotive industry to reduce mass. The Finite Element Method (FEM) is quite successful to simulate metal forming processes but accuracy depends both on the constitutive laws used and their material parameters identification. Common phenomenological models roughly consist in the fitting of functions on experimental results and do not provide any predictive character for different metals from the same grade. Therefore, the use of accurate plasticity models based on physics would increase predictive capability, reduce parameter identification cost and allow for robust and time-effective finite element simulations.

For this purpose, a 3D physically-based model at large strain with dislocation density evolution approach was presented in IDDRG2009 by the authors [1]. This approach can be decomposed as a combination of isotropic and kinematic contributions. The model enables the description of work-hardening's behaviour for different simple loading paths (i.e. uni-axial tensile, simple shear and Bauschinger tests) taking into account several data from microstructure (i.e. grain size, texture, etc…). The originality of this model consists in the introduction of microstructure data in a classical phenomenological model in order to achieve work-hardening's predictive character for different metals from the same grade. Indeed, thanks to a microstructure parameter set for IF steels, it is possible to describe work-hardening's behaviour for different steels of grain sizes varying in the 8.5-22µm value range by only changing the mean grain size and initial yield stress values.

Forming Limit Diagrams (FLDs) have been empirically constructed to describe the strain states at which a highly localized zone of thinning, or necking, becomes visible on the surface of sheet metals. FLDs can be experimentally obtained through Marciniak Stretch test, which is a modified dome test. It was designed to overcome the severe strain gradients developed by the traditional dome tests using a hemispherical punch (e.g. Nakajima test). Many automotive manufacturers use Marciniak Stretch test as a validation tool before simulating real parts.

The work described is an implementation [2] of a 3D dislocation based model in ABAQUS/Explicit together with its validation on a finite element (FE) Marciniak Stretch test. In order to assess the performance and relevance of the 3D dislocation based model in the simulation of industrial forming applications, FLDs will be plotted and compared to experimental results for different IF steels.

References

[1] *« Work-hardening prediction using a dislocation based model for aluminium automotive alloys »*, *Proceedings of the 2009 International Deep Drawing Research Group conference,* S. Bouvier, T. Carvalho-Resende and S-.S. Sablin, pp. 197-205, 2009.

[2] *« Contribution à la modélisation de la mise en forme des tôles métalliques/ application au retour élastique et à la localisation »*, *PhD Thesis,* B. Haddag, 2007.